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Seeking no War, Achieving no Peace

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Seeking no War, Achieving no Peace

Tommy Andersson[y] and Conan Mukherjee[z]

Abstract

This paper models "no war, no peace" situations in a game theoretical framework where two countries are engaged in a standoff over a military sector. The first main objective is to identify rational grounds for such situations and, more precisely, explicit equilibria that leads to such situations. It is demonstrated that both countries get the same payoff from being in this continuous state of perpetual hostility and, moreover, that "no war, no peace" situations can be explained only if the countries perceive an equal measure of military advantage by controlling the area. Given this insight, the second objective of the paper is to provide insights about how "no war, no peace" situations can be resolved. Two different pathways are suggested. The first is idealistic and based on mutual trust whereas the second is based on deterrence meaning that both countries impose a threat of using armed force against the other country in their respective military doctrines.

Keywords: game theory, infinite horizon game, stationary strategies, "no war, no peace", Siachen conflict.

JEL Classification: C73, H56.

1 Introduction

Between 1989 and 2010, at least 32 major peace accords and even more ceasefires were negotiated around the world. Despite this, many of the involved countries and regions experience a "no war, no peace" situation, i.e., a situation characterized by continued insecurity, low-level violence, inter-group hostility, and persistence of the factors that sparked and sustained the conflict (Mac Ginty, 2010). Well-known examples include the 1989 post-civil war reconstruction in

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Lebanon, the 2003 ceasefire agreement in Sri Lanka, the two decade long and ongoing border conflict between Ethiopia and Eritrea, and the never-ending conflict between the nuclear states India and Pakistan over the Siachen Glacier. This paper models "no war, no peace" situations in a game theoretical framework where two countries are engaged in a standoff over a strategically important military sector. Although the conflict over the Siachen Glacier will serve as the leading example, the conclusions that follow from the analysis are not restricted to this particular conflict.

The foundation of the conflict over the Siachen Glacier dates back to 1949 when the Karachi Agreement was signed to establish a ceasefire line in Kashmir following the Indo–Pakistani war of 1947 (Wirsing, 1998). This Agreement did not clearly specify which country that controlled the Siachen Glacier. It only demarcated the ceasefire line till the grid point NJ9842 at the foot of the glacier, and left a vague description that this line was supposed to run "thence north to the glaciers".[1] Thus, this largely inaccessible terrain beyond NJ9842 was not delimited, and so, neither India nor Pakistan had any permanent military presence in the area prior to 1984. The military standoff on the Siachen Glacier began in 1984 when India gained control over the glacier to preempt the seizure of the passes by the Pakistan army.[2] In response to these developments, the Pakistan army initiated an operation to displace the Indian troops on the key passes. This operation led to the first armed confrontation on the glacier on April 25, 1984. The following 19 years, there was multiple of low-level violence confrontations[3] between the Indian and the Pakistan armies in the area. It was not until 2003 that a ceasefire went into effect. However, even after this ceasefire agreement, both India and Pakistan have troops stationed in the area with India having maintained control over the glacier since 1984.

To model a "no war, no peace" situation, an infinite horizon game with two countries is considered.[4] One can think of one of the countries as the incumbent and the other as the challenger (in the conflict over the Siachen Glacier, India plays the role of the incumbent and Pakistan the role of the challenger). Each country is guided by her military doctrine or, equivalently, by a fundamental set of principles that guide her military forces whenever pursuing national security objectives. Based on their respective doctrines, the countries form their military strategies. Given the deadlock situation which is the very foundation of a "no war, no peace" situation, it is

[1]See Baghel and Nüsser (2015) and Hussain (2012). In the latter article, the author, who is a retired Pakistani brigadier, posits that this line is interpreted by Pakistan as running east to the glacier.

[2]As discussed in Baghel and Nüsser (2015), Bearak (1999), Hussain (2012) and Fedarko (2003), the Indian fears of such possible seizure were apparently generated by Pakistan's grant of sovereign permission to European expedition and mountaineering teams to visit this area. It is also argued that some intelligence about Pakistan army placing a huge order of heavy winter clothing was interpreted by Indian military planners as preparation for such a seizure.

[3]In fact, it has been estimated that around 97 percent of the military casualties on the Siachen Glacier between 1984 and 2003 not was due to enemy firing but instead a consequence of severe weather conditions, altitude, avalanches, etc. (Ives, 2004).

[4]Infinite horizon war games have recently been considered by, e.g., Debs and Monteiro (2014); Fearon (2004, 2007); Jackson and Morelli (2009).

not unreasonable to assume that the countries have non-changing military doctrines. India and Pakistan, for example, have fought over the same sectors in the state of Jammu and Kashmir, four times in seventy years of their co-existence, and India had the same official military doctrine between 1947 and 2017. In the considered game theoretical framework, this means that the countries have stationary strategies. Consequently, both countries, depending on whether they are an incumbent or a challenger, must use the same rule of choosing an action at all times. The actions that the incumbent country chooses between is either to stay or to retreat from the area. After the incumbent country has made her move, the challenger country chooses either to occupy or to not occupy the area. If the incumbent country decides to stay and the challenger country decides to occupy, there will be an armed confrontation.

To formally analyze "no war, no peace" situations, the concept must be defined in terms of military doctrines or, equivalently, in terms of the stationary strategies played by the two countries. Before presenting such definition, we make three observations pertaining to the Siachen conflict and mountain warfare in general. First, it is not unreasonable to suppose that the military doctrine of the incumbent country specifies that the country should stay in the area and maintain control over it. This would, in fact, be consistent with the mountain warfare tactics called *Gebirgskreig*, which was developed during World War I.[5] Indeed, this is also the strategy adopted by India since 1984 when India occupied the Siachen Glacier and became the incumbent in the same, but still cannot find reasons to make peace as equals. From the analysis, it is also clear that a "no war, no peace" situation cannot be explained by patience, i.e., the results are independent of the discount factors. Neither can the situation be explained merely by the euphoria a country experiences when defeating its opponent in an armed confrontation. As will be explained in more detail later, a rational explanation to a "no war, no peace" situation is that both countries perceive an equal measure of military advantage by controlling the area.

The latter conclusion will also be helpful in providing insights about how "no war, no peace" situations can be resolved. This paper adopts the natural view that a "no war, no peace" situation is resolved when both countries agree to retreat whenever being in the position of an incumbent country and, furthermore, not to occupy whenever being in the position of a challenger country if the incumbent country decides to retreat. In such event, the area gets mutually designated to be no man's land, presumably through a sovereign treaty, and both countries will, consequently, cease to have their armies stationed in the area. Hence, a first step to obtain a resolution is that both countries must change their military doctrines, i.e., their stationary strategies. However, this alone will not lead to an equilibrium outcome. As will be demonstrated, such a change in the military doctrines must also be accompanied with substantial peace activism in order for the considered strategy profiles to constitute an equilibrium.

Two different strategy profiles that resolve the "no war, no peace" situation in combination with peace activism are identified, and both of them have been observed to play key roles in historical conflicts. The first is idealistic in the sense that a resolution is achieved without imposing any threats of retaliation. Instead, it relies on mutual trust and good faith as, e.g., the solution to the Argentine–Brazilian détente of the late 1970s (Oelsner, 2007). The second is based on deterrence meaning that both countries imposes a threat of using armed force against the other country in their respective military doctrines. This type of doctrine was popularized in the aftermath of World War II when the rivalry between United States and Soviet Union was at its peak.

While the earliest economic analysis of war can be traced back to Schelling (1966), there has been a spurt in theoretical studies of war in recent years.[7] In this emerging literature, the paper that is most closely related to our paper is Yared (2010). In his paper, conflicts between sovereign states are (exactly as in our paper) modelled as a discrete time dynamic game. However, as will be explained next, the paper by Yared (2010) differs from our paper in many aspects.

In Yared (2010), conflicts are modeled as a game between two countries in a setting where both countries agree and acknowledge that one is mightier than the other in terms of military and economic resources. Their engagement essentially translates into determination of a kind of protection offering or "concession" that must be made by the (mutually acknowledged) weaker state in every time period to escape war being thrust on it. A state variable determines whether the weaker state can or cannot afford to make such concessions - and the periods where suitable offerings are made to avert, are labelled as periods of *peace*. Further, the decision to inflict a war

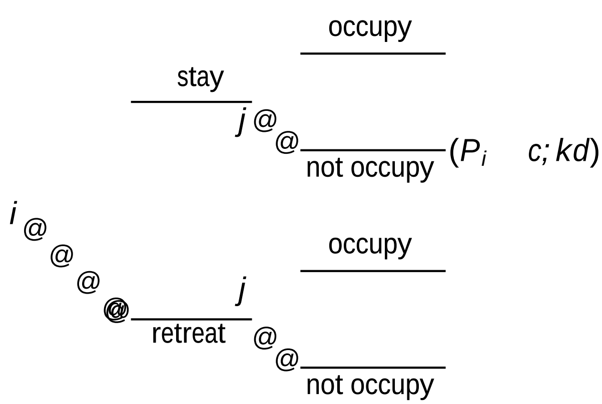
[7] Some such papers are Baliga and Sjöström (2004), Chassang and Miquel (2010), Fearon (1995), Leventoğlu and Slantchev (2007), Powell (1999), Powell (2004), and Schwarz and Sonin (2007).

is allowed to be probabilistic as well as history dependent.

We find that there are situations where the model of Yared (2010) is difficult to motivate. For example, it is difficult to conceptualize peace as an artefact of extortion in modern times. While payments of money did conclude and avoid armed conflicts in past centuries (like the Barbary Wars during 1805–1815), modern international relations architecture under the leadership of

2.1 Preliminaries

Consider an infinite horizon game G with two players, denoted by 1 and 2. The players should be thought of as two countries involved in a conflict over a sector of crucial military significance that, at most, one of them can control. Let G^i denote the infinite horizon game where country i controls the military sector in the first time period of the game, i.e., in time period $t = 1$. The game $G \in \{G^1; G^2\}$ is defined conditionally on which country that controls the military sector at $t = 1$, i.e., $G = G^i$ if and only if country i controls the military sector at $t = 1$. This paper focuses, without loss of generality, on the game $G = G^1$.


occupy
stay
j
not occupy
(Pi c; kd)
i
occupy
j
retreat
not occupy

The considered strategy space gives rise to four different payoff pairs that may be realized in any given stage game G_t^i for time period t. These payoff pairs are described next together with the implied stage games for time period $t+1$. The game tree is also illustrated in Figure 1.

The incumbent country i

Assumption 1.

However, in this paper, we consider a weaker definition of a “no war, no peace” situation where the incumbent country in time period $t = 1$ chooses strategy s and the challenger country in period $t = 1$ adopt the strategy $[s; (no; o)]$. Note that a strategy profile based on these premisses will never lead to an armed confrontation as countries play stationary strategies. Further, this definition of a “no war, no peace” situation also leaves room for different actions for the incumbent country in time period $t = 1$ whenever this country is in the position of a challenger. That is, the definition only states that the incumbent country in time period $t = 1$ must adopt a strategy of type $[s; a]$ for some $a \; 2 \; f(o; o); (o; no); (no; o); (no; no)g$.

Our first theorem captures the tragedy of the status quo in such situations. More precisely, in the language of the considered game, the theorem states that if there exists an equilibrium path of G^1 where “no war, no peace” situation reigns, then at least one of the countries prefer to be a challenger than an incumbent in all stage games. In context of the conflict over Siachen Glacier, this means that the unending competition for the glacier makes sense only if either of India and Pakistan (or both of them) has no inherent desire to posses the peak, irrespective of its perceived military value or associated costs.

Theorem 1. Fix any $i = 1; 2$. If there exists an SPNE that never leads to a peaceful resolution or an armed confrontation on equilibrium path in G^i, then there exists a country j such that $P_j \quad c \quad kd$.

Thus, Theorem 1 emphasizes that the essence of a “no war, no peace” situation can only be a deeply entrenched fear of being cheated over territorial control, which forces countries to disregard the obvious incentives to vacate the peak.

3.1 Rational Basis for “No War, No Peace” Situations

Given that instances of “no war, no peace” situations has been observed across the world over time, it is important to identify rational grounds for such hostility and, more precisely, explicit equilibria that lead to “no war, no peace” situations, which can then be used to identify possible resolutions to “no war, no peace” situations.

The following two results shed some light on this. The first of these equilibria is the symmetric equilibrium ^{0} where $^0_i := [s; (no; o)]$ for both countries i. The behaviour underscored by this strategy combination is one of deep distrust, where no country attacks the other to capture the sector but waits for a chance to occ0(w)10(aits)-250(for)-250(a)-250(chance)-250((cothe)-22899(comb260(ic

Two different strategy profiles that resolve a "no war, no peace" situation will be discussed in this section. The first is idealistic in the sense that a resolution is achieved without imposing any threats of retaliation. Instead, it relies on mutual trust and good faith. The second is based on deterrence meaning that both countries imposes a threat of using armed force against the other country. However, as we argue below, both these resolutions must be accompanied by substantial peace activism in order to be successful.

The first resolution strategy profile mirrors the common idea that trust and good faith can lead to resolutions of conflicts. For example, Oelsner (2007, p.257) reports the Argentine–Brazilian détente of the late 1970s and the determination to build a zone of positive peace in Latin America's southern cone, and writes:

> "... over the last six decades, some regions have overcome the security dilemma and states have constructed peaceful relationships based on mutual trust and confidence, resembling friendship at the interstate levels."

Such an ideal situation is described in our setting by the strategy profile ~ where $\sim_i := [r; (no; no)]$ for both countries i. However, as the next result shows, such optimism will be realized if and only if both countries find peace "sufficiently attractive". More precisely, ~ can constitute an equilibrium only as a result of aggressive peace activism that underlines the returns to peace and excruciating costs to bear in this standoff. In other words, while mutual trust is indispensable to adopt the strategy profile ~, a greater amount of public debate and engagement is needed to generate a consensus that $P_i \quad c \quad H$ for both countries i.

Theorem 4. The strategy profile

the strategy profile where $_i$:= $[r; (o; no)]$ for both countries i. However, this retaliation strategy must not only be accompanied with aggressive peace activism (as the above described idealistic equilibrium ~) but also with bolstering military and technical capabilities which gives the incumbent country an invincible position of strength. The latter is captured by a "sufficiently high" probability of winning the battle for the incumbent country (in fact a stronger condition than the one in Assumption 1(i)). Another way to paraphrase this condition is that one cannot hope to achieve a peaceful resolution of the conflict only by peace activism, both countries would rationally find reasons to enter peace negotiations only when the degree of invincibility of an incumbent is sufficiently high. In this sense, the ever increasing military expenditures in both India and Pakistan may not be as inimical for peace as thought conventionally.[12]

Theorem 5. The strategy profile is an SPNE if and only if, for each $i \in \{1, 2\}$, P_i c H and 1 $\frac{kd}{P_i + W}$ p.

4 Conclusions

One of the innovations in this paper is to model "no war, no peace" situations as infinite horizon games where the involved countries are guided my their respective military doctrines. These doctrines are, by assumption, constant over time (India, for example, had the same military doctrine between 1947 and 2017). This in turn, implies that players can be assumed to play stationary strategies. Given this, it has been demonstrated that a "no war, no peace" situation indeed can constitute an equilibrium. However, these type of equilibria are not very robust as their existence rests on very particular arrangements of parameters and, more precisely, on the fact that both countries perceive an equal measure of military advantage to controlling the military sector. As explained in this paper, this conclusion also hints on two possible pathways toward a resolution of "no war, no peace" situations.

Most assumptions in this paper are intuitive in nature. Perhaps the most difficult assumption to motivate is the regularity condition that both countries find more gratifying to defeat the other in battle, than to bide time in trying to capture the military sector without any confrontation. Whether or not this is a too strong assumption can be debated. Naturally, more research is needed not only to find natural and realistic assumptions, but also to fully understand the rational behind "no war, no peace" situations and possible resolutions to them. This paper and the findings in it should, therefore, be seen as one piece in a larger puzzle that not yet is fully understood.

[12]Between 2007 to 2009, India's defence budget increased from 24 billion USD to 40 billion USD. Observing this, Pakistan increased its defence budget by around 32 percent. *Source:*

Appendix: Proofs

A well-known result that will be used repeatedly in the proofs is that, in any dynamic game, a strategy profile is a SPNE if and only if it satisfies the one-stage deviation principle. A strategy profile satisfies the one-stage deviation principle if neither country (i.e., player) can increase their payoff by deviating unilaterally from their strategy in any single stage game and then returning to the specified strategy thereafter. The subgame G^1 is, without loss of generality, considered throughout the Appendix.

Note first that the above condition must hold for all $\ \ 2\ (\ ;1)$ by our definition of equilibrium. Note next that $x_2^2(\ )$ is the only unknown value in condition (2). By construction, $x_2^2(\ )$ can take four different values, and these values depend on the kind of actions prescribed by   to the countries in stage game G^2. These four possibilities will be discussed in the following cases (a.i)–(a.iv) to establish that the condition $P_2 \quad c \quad kd$ must hold.

Case (a.i) *Country* 2 *retreats and country* 1 *chooses not to occupy in* G^2. Note that this case pertains to the situation where the supposed equilibrium   leads to a resolution of the conflict in stage game G^2 leading to $x_2^2(\ ) = \frac{H}{1}$. Imputing this value in condition (2), as   converges to 1 in limit, it follows that:

$$H \quad kd: \tag{3}$$

Now, in subgame G^2, the one-stage deviation by country 2 of staying (instead of retreating as prescribed by) would give a payoff of:

$$P_2 \quad c + \ x_2^2(\ ) = P_2 \quad c + \frac{H}{1}; \tag{4}$$

if   prescribes country 1 to not occupy when country 2 stays in G^2, and:

$$p\ \ P_2 + W + \ \ x_2^2(\ )\ \ + (1 \quad p)(0 + \ \ x_2^1(\ )) = p\ \ \ P_2 + W + \frac{H}{1}\ \ \ + (1 \quad p)\frac{kd}{1}; \tag{5}$$

if   prescribes country 1 to occupy when country 2 stays in G^2.

Since our notion of equilibrium implies that no one-stage deviation is profitable, as   converges to 1 in limit, equation (4) implies that $P_2 \quad c \quad H$, and so, by equation (3) we get that $P_2 \quad c \quad kd$. Arguing similarly, by equation (5) we get that:

$$(1 \qquad)p(P_2 + W) + p\ \ H + (1 \quad p)\ \ kd \quad\ H;$$

which implies that:

$$(1 \qquad)p(P_2 + W) + (1 \quad p)\ \ kd \quad\ H(1 \quad p\ \ ):$$

The latter inequality, when taken together with condition (3), implies that $(1 \qquad)p(P_2 + W) + (1 \quad p)\ \ kd \quad\ kd(1 \quad p\ \ )$, which is equivalent to the condition $p(P_2 + W) \quad\ kd$. Now, by Assumption 1(ii), $kd < \frac{P_2+W}{2}$, we get that $p < \frac{1}{2}$ which contradicts Assumption 1(i). Therefore,   must not prescribe country 1 to occupy when country 2 stays in G^2, and so, only the equations (3) and (4) can hold implying that $P_2 \quad c \quad kd$.

chooses to occupy, there will be an armed confrontation leading to an expected payoff:

$$p(0 + \quad x_1^2(\quad)) + (1 \quad p)[P_1 + W + \quad x_1^1(\quad)] = \frac{(P_1 \quad c) + (1 \quad\quad)(1 \quad p)(P_1 + W)}{1}: \qquad (6)$$

If, on the other hand, country 1 chooses not to occupy, the consequent expected payoff equals:

$$kd + \quad x_1^2(\quad) = \frac{(P_1 \quad c) + (1 \quad\quad)kd}{1}: \qquad (7)$$

By Assumption 1 and conditions (6) and (7), country 1 gets a greater payoff by not occupying whenever country 2 stays in G^2 under this case. Hence, the one-stage deviation of country 2 where she stays in the stage game G^2

prescribes country 2 to occupy at time $t = 1$. Hence, $x_1^1(\ ) = d + \ x_1^2(\ )$ and $x_2^1(\ ) = P_2 \quad c + \ x_2^2$, and country 2 is the incumbent at time $t = 2$ on the equilibrium path arising out of play of . Note that unlike Case (a), now G^2 is a stage that is reached on the equilibrium path implied by in G^1. And so, must not imply a peaceful resolution or armed confrontation in G^2 (or equivalently in G^2). Therefore, now $x_2^2(\ )$ can only take two different values, and as before, these values depend on the kind of actions prescribed by to the countries in stage game G^2. We analyze these possibilities as separate cases (b.i)–(b.ii) below, and show that $P_2 \quad c \quad kd$.

Case (b.i) *Country* 2 *retreats and country* 1 *chooses to occupy in* G^2. In this situation, it follows that $x_1^2(\ ) = P_1 \quad c + \ x_1^1(\ )$ where $x_1^1(\ ) = d + \ (P_1 \quad c + \ x_1^1(\ ))$. From these two conditions, the following must hold:

$$x_1^2(\ ) \quad x_1^1(\ ) = \frac{P_1 \quad c \quad d}{1 + }: \tag{8}$$

Consider next the unilateral one-stage deviation by country 1 in the stage game G^1 at time period $t = 1$, where country 1 stays instead of retreating. This action will lead to an armed confrontation if, at this off-equilibrium path, country 2 chooses to occupy. Now, occupying would give country 1 an expected payoff $p \ x_1^2(\ ) + (1 \quad p)[P_1 + W + \ x_1^1(\ )]$ whereas not occupying would give country 1 payoff $kd + \ x_1^2(\ )$. The difference in payoff between occupying and not occupying

Proof. Fix an $i = 1, 2$. To prove necessity, suppose that σ' is an equilibrium for the game G^i. Then there exists some $\underline{\delta} \in (0, 1)$ such that the strategy profile σ' is a SPNE for all $\delta \in (\underline{\delta}, 1)$. Furthermore, for all $\delta \in (\underline{\delta}, 1)$, it holds that $x_1^1(\delta) = P_1 - c + \delta x_1^1(\delta)$ and $x_1^2(\delta) = kd + \delta x_1^2(\delta)$, implying that:

$$(x_1^1(\delta), x_2^1(\delta)) = \left(\frac{P_1 - c}{1 - \delta}, \frac{kd}{1 - \delta} \right).$$

By identical arguments, it follows that:

$$(x_1^2(\delta), x_2^2(\delta)) = \left(\frac{kd}{1 - \delta}, \frac{P_2 - c}{1 - \delta} \right).$$

Recall next that each country i makes a move either (i) as an incumbent, or (ii) as a challenger responding to the other country j choosing to stay, or (iii) as a challenger responding to the other country j choosing to retreat. Further, by stationarity, the action choices at each of these nodes must not vary over time. Because σ' is a SPNE, by assumption, the one-stage deviation property requires that the following inequalities, that correspond to cases (i)–(iii), must hold for all $\delta \in (\underline{\delta}, 1)$:

(i) $[d + \delta x_1^2(\delta)] \leq x_1^1(\delta) \Leftrightarrow (1 + \delta(k - 1))d \leq P_1 - c$,

(ii) $[p\, x_1^2(\delta) + (1 - p)(P_1 + W + \delta x_1^1(\delta))] \leq x_1^2(\delta)$

$\Leftrightarrow \frac{(1-\delta)(1-p)(P_1+W) + \delta(P_1 - c)(1-p)}{1 - \delta p} \leq kd$,

(iii) $\frac{\delta H}{1 - \delta} \leq [P_1 - c + \delta x_1^1(\delta)] \Leftrightarrow \delta H \leq P_1 - c$.

Because the above inequalities must hold for all $\delta \in (\underline{\delta}, 1)$, they must obviously hold in limit as $\delta \to 1$. But this implies that $kd = P_1 - c \geq H$. By similar arguments, it can be demonstrated that $kd = P_2 - c \geq H$.

Now, from the proof of necessity above, it can easily be seen that parameter restrictions $P_i - c = kd \geq H; \forall i = 1, 2$ and Assumption 1 imply that σ' satisfies the one-stage deviation property for all possible values of δ. Hence, the proof of sufficiency follows. □

Theorem 3. The strategy profile σ'' is an SPNE if and only if $P_i - c = kd = H$ for each $i \in \{1, 2\}$.

Proof. Fix an $i = 1, 2$. To prove necessity, suppose that σ'' is an equilibrium for the game G^i. Then there exists some $\underline{\delta} \in (0, 1)$ such that the strategy profile σ'' is a SPNE for all $\delta \in (\underline{\delta}, 1)$. Furthermore, for all $\delta \in (\underline{\delta}, 1)$ and for all $i \neq j \in \{1, 2\}$, it holds that $x_i^i(\delta) = \frac{P_i - c}{1 - \delta}$ and $x_j^i(\delta) = x_i^j(\delta) = \frac{kd}{1 - \delta}$. As in the proof of Theorem 2, each country i makes a move either (i) as an incumbent, or (ii) as a challenger responding to the other country j choosing to stay, or (iii) as a challenger responding to the other country j choosing to retreat. Because ^{00} is a SPNE, by assumption, the one-stage deviation property requires that the following inequalities, that correspond to cases (i)–(iii), must hold for country 1 for all $2\ (\ ;1)$:

(1.i) $[d + \ x_1^2(\ )] \quad x_1^1(\ ) \quad , \quad (1 + \ (k \quad 1))d \quad P_1 \quad c$,

(1.ii) $[p\ x_1^2(\ ) + (1 \quad p)(P_1 + W + \ x_1^1(\ ))] \quad x_1^2(\ )$

$$, \quad \frac{(1 \quad)(1 \quad p)(P_1 + W) + \ (P_1 \quad c)(1 \quad p)}{1 \quad p} \quad kd,$$

(1.iii) $[P_1 \quad c + \ x_1^1(\ )] \quad \frac{H}{1} \quad , \quad P_1 \quad c \quad H$.

By similar arguments, the following inequalities must hold for country 2 for all $2\ (\ ;1)$:

(2.i) $\frac{H}{1} \quad x_2^2 \quad , \quad H \quad P_2 \quad c$,

(2.ii) $[p\ x_2^1(\ ) + (1 \quad p)(P_2 + W + \ x_2^2(\ ))] \quad x_2^1(\ )$

$$, \quad \frac{(1 \quad)(1 \quad p)(P_2 + W) + \ (P_2 \quad c)(1 \quad p)}{1 \quad p} \quad kd,$$

(2.iii) $\frac{H}{1} \quad \frac{P_2 \quad c}{1} \quad , \quad H \quad P_2 \quad c$.

Because the inequalities (1.i)–(1.iii) and (2.i)–(2.iii) must hold for all $2\ (\ ;1)$, they must obviously hold in limit as $\ ! \ 1$. But this implies that $kd \quad P_1 \quad c \quad H \quad P_2 \quad c \quad kd$, and so, the necessity part of the proof follows.

As before, from the proof of necessity above, it can easily be seen that parameter restrictions $P_i \quad c = kd \quad H; 8\ i = 1; 2$ and Assumption 1 imply that ^{0} satisfies the one-stage deviation property for all possible values of . Hence, the proof of sufficiency follows. □

Because the proofs of Theorems 4 and 5 are almost identical, only latter of them is proved in this Appendix.

Theorem 5. The strategy profile is an SPNE if and only if, for each $i = 1; 2$, $P_i \quad c \quad H$ and $1 \quad \frac{kd}{P_i + W} \quad p$.

Proof. Fix an $i = 1; 2$. To prove necessity, suppose that is an equilibrium for the game G^i. Then there exists some $2\ (0; 1)$ such that the strategy profile is a SPNE for all

(i) $P_i \quad c + \; x_i^i(\;) \quad x_i^i(\;) \;\; , \;\; P_i \quad c \quad H$,

(ii) $\; px_i^j(\;) + (1 \quad p)(P_i + W + \; x_i^i(\;)) \quad x_i^j(\;) \;\; , \;\; 1 \quad \frac{kd}{P_i+W} \quad p$,

(iii) $P_i \quad c + \; x_i^i(\;) \quad x_i^i(\;) \;\; , \;\; P_i \quad c \quad H$.

The necessity result now follows directly from the above inequalities.

Finally, from the proof of necessity above, it can easily be seen that parameter restrictions $P_i \quad c \quad H; 8\, i = 1; 2$ and $1 \quad \frac{kd}{P_i+W} \quad p$ imply that $\;^0$ satisfies the one-stage deviation property for all possible values of . WHence, the proof of sufficiency follows. □

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